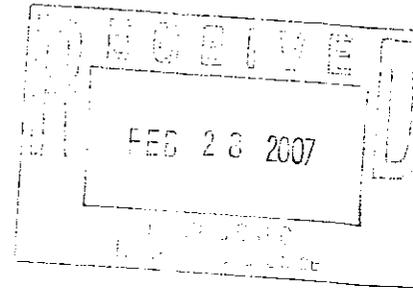


EMERGENCY ACTION PLAN

FOR

COWPATH DAM AND SULLIVAN DAM

SHELBY, MONTANA



Owner-Operator: City of Shelby, Montana
112 1st St S
Shelby MT 59474

Mayor: Larry J. Bonderud

Prepared by: Kadrmas, Lee & Jackson
1075 N Rodney, Suite 101
Helena, MT 59625-1567

Updated: January 25, 2007

If Cowpath Dam or Sullivan Dam is failing or failure seems imminent, call:

All Emergency Services 911/434-5585

Toole County Disaster and Emergency Services (24 hours)

Darrel Stafford, Coordinator, Shelby . . Home . 339-2389
Cell . 450-8972

Diana Grimm, Deputy Coordinator, Shelby . Work . 424-8390

Larry J. Bonderud, Mayor City Hall . 434-5222
Business . 434-5196
Home . 434-5029
Cell . 450-5196

Bill Moritz, City Superintendent City Shop . 434-5564
Home . 424-2183
Cell . 450-0932

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	
PURPOSE	1
DESCRIPTION OF DAMS	1
ACCESS TO DAMS	1
HAZARD AREA	1
RESPONSIBILITY AND AUTHORITY	3
PERIODIC REVIEW/UPDATE	3
APPROVAL	3

NOTIFICATION PROCEDURES	
IMMINENT OR ACTUAL FAILURE	4
POTENTIALLY HAZARDOUS SITUATION	6
POSTING OF THE NOTIFICATION FLOWCART AND DISTRIBUTION OF THE EMERGENCY ACTION PLAN	6

MITIGATION ACTIONS	
POTENTIAL PROBLEMS AND IMMEDIATE RESPONSE ACTIONS	8
EMERGENCY SUPPLIES AND RESOURCES	8
LOCAL CONTRACTORS	8
ENGINEERS	8

APPENDICES

Appendix A - Technical Data for Cowpath Dam and Sullivan Dam	
Appendix B - Inundation and Evacuation Map	
Appendix C - Telephone Directory	
Appendix D - Dam Incident Report Form	
Appendix E - Potential Problems, Causes, Consequences And Action	

FIGURES

Figure 1 Vicinity Map	2
Figure 2 Actual or Imminent Failure Notification Flowchart	5
Figure 3 Potentially Hazardous Situation Notification Flowchart	7

INTRODUCTION

Purpose

The purpose of this emergency action plan (EAP) is primarily to safeguard the lives of secondarily to reduce property damage to the citizens of Shelby in the event of flooding caused by a failure of Sullivan Dam or Cowpath Dam.

Description of Dams

The Cowpath Dam/Sullivan Dam facility is located in the south 1/2 of Section 15, and the north 1/2 of Section 22, Township 32 North (T32N), Range 2 West (2W), Toole County, Montana. The dams are located on an unnamed tributary to the Marias River. The facility is owned by the City of Shelby and is used as a flood protection, recreation, and fish and wildlife storage facility. Technical data pertaining to the Cowpath Dam/Sullivan Dam facility are listed in Appendix A. The locations of the dams are shown on Figure 1.

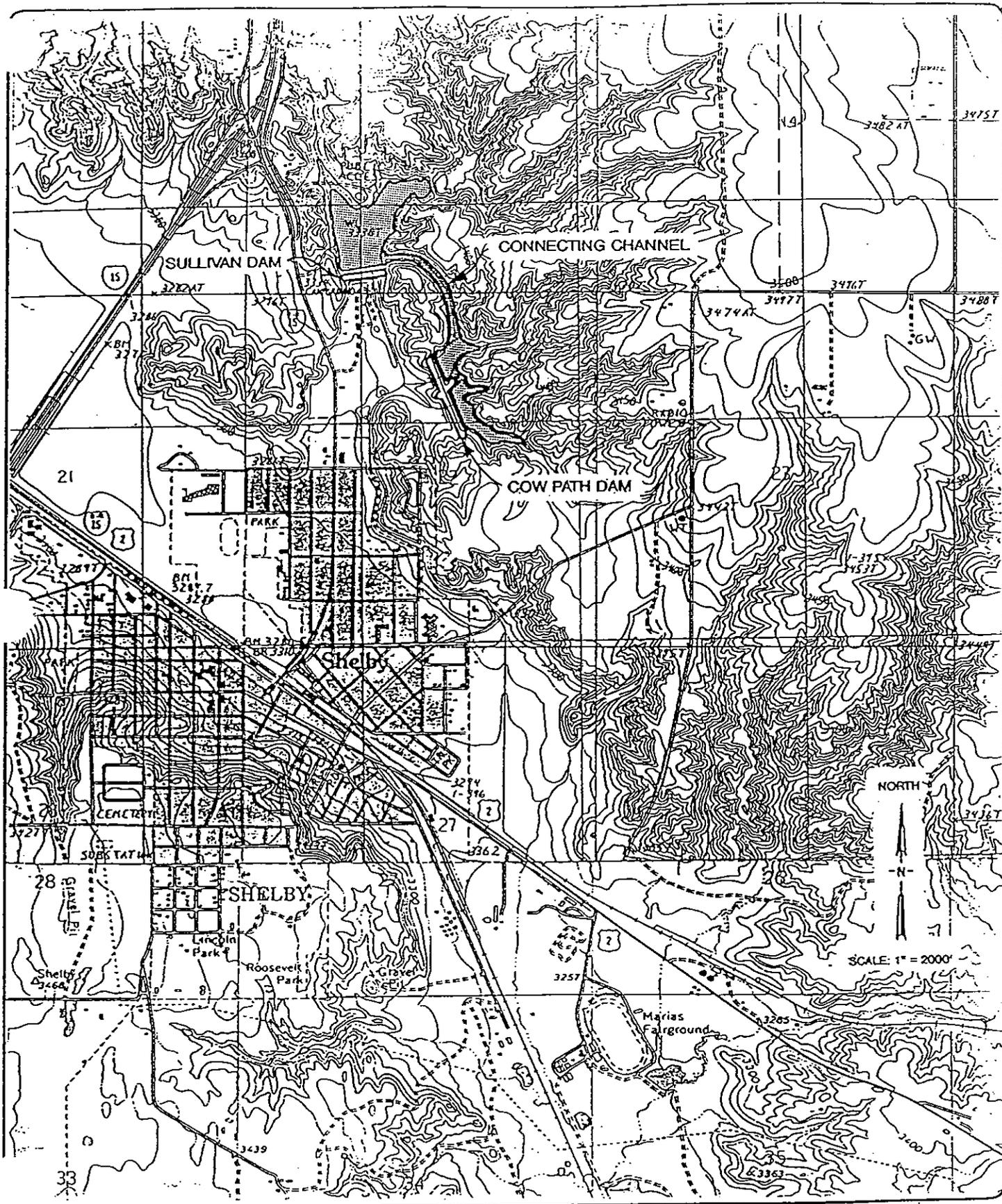
Access to Dams

The Cowpath Dam/Sullivan Dam facility is located approximately one-half mile north of Shelby along Business Route 15. Two gravel roads provide access to the dams from the highway.

Hazard Area

The evacuation area extends through the City of Shelby and along the unnamed tributary to the confluence with the Marias River approximately seven miles to the south, as shown in Appendix B. Hazards include the possible inundation of commercial and residential buildings, the railroad and State Highway 2. Inundation and evacuation maps are included in Appendix B.

FIGURE 1 - VICINITY MAP



**COW PATH AND SULLIVAN DAMS
VICINITY MAP**

FIGURE 1

**HKA ASSOCIATES
ENGINEERS - PLANNERS
8M334.101 JULY 1991**

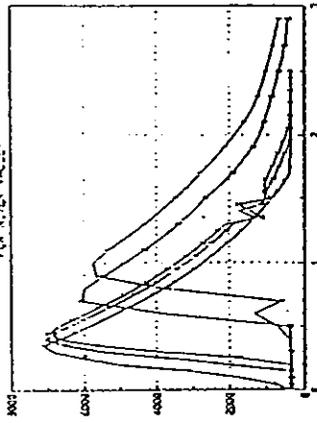
SIELAIR
3427.6
3430

Lake Sneloie Dam Break Analysis

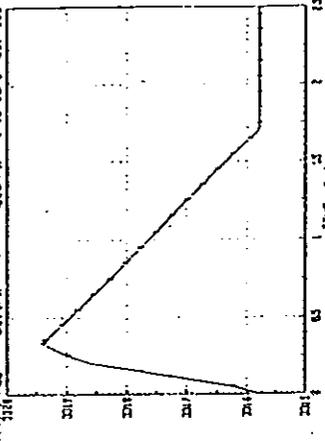
Location	Time (hr)		Elev (cfs)		Elevation (nat)		Depth (ft)	
	C-X	PXZ	C-X	PXZ	C-X	PXZ	C-X	PXZ
0.00	0.33	0.67	7300	58590	3319	3327	5	13
0.38	0.40	0.70	7070	56890	3304	3309	4	9
0.55	0.45	0.73	7000	56310	3298	3303	3	8
1.04	0.74	0.82	6190	53250	3282	3287	2	7

Clear-weather
breach
hydrographs

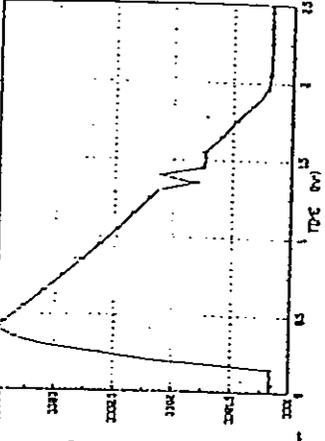
COMBINED FLOW HYDROGRAPHS
FOR UPPER VALLEY



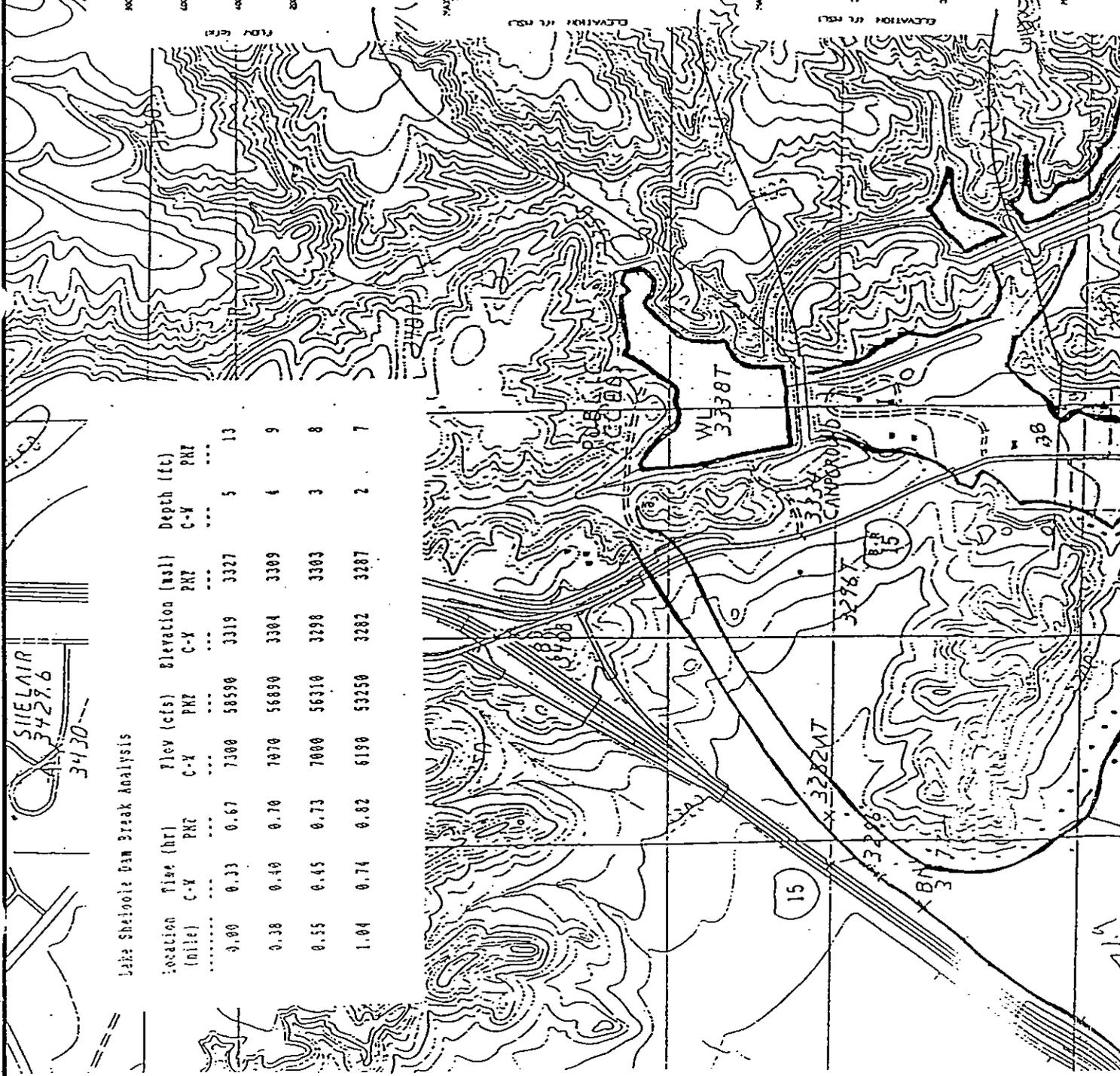
STAGE HYDROGRAPH (CG: 0000 m)
MAX. STAGE 5396 ft. AT 3300-hr. GAGE ZERO 3314.220 ft.



STAGE HYDROGRAPH (CG: 550 m)
MAX. STAGE 3379 ft. AT 1480-hr. GAGE ZERO 3300.220 ft.



STAGE HYDROGRAPH (CG: 550 m)
MAX. STAGE 3379 ft. AT 1480-hr. GAGE ZERO 3300.220 ft.



NOTIFICATION PROCEDURES

NOTIFICATION PROCEDURES

Imminent or Actual Failure

If you reasonable believe a dam failure is imminent or likely to occur, begin the "Actual or Imminent Failure" warning procedure illustrated on Figure 2 (page 5). If you reasonably believe a failure is not imminent and not likely to occur, follow the "Potentially Hazardous Situation" procedure on Figure 3 (page 7). **It is very important that you give full weight to downstream public safety while deciding which procedure to follow.** If Cowpath Dam and/or Sullivan Dam are failing, two things must be done immediately: (1) the hazard area downstream from the dam must be evacuated, and (2) any steps that might save the dam or reduce damage to the dam or hazard area downstream should be taken. (Refer to the map in Appendix B to determine the areas that are likely to be inundated if the dam fails). The evacuation should be initiated as shown in Figure 2.

It is the observer's responsibility to:

- a. Call the Emergency Services Dispatch Center (911) and Disaster and Emergency Services. Be sure to say, "This is an emergency." They will call other authorities and the media and begin the evacuation.
- b. Do whatever is necessary to bring anyone in immediate danger to safety. This includes someone on the dams, directly below the dams, or boating on the reservoir, or evacuees if so directed by the sheriff.
- c. Keep in frequent touch with the Sheriff's Office. They will tell you how to handle the emergency.
- d. If all means of communication are lost:
 - Try to find out why
 - Try to get to another radio or telephone that works
 - Get someone else to try to reestablish communications

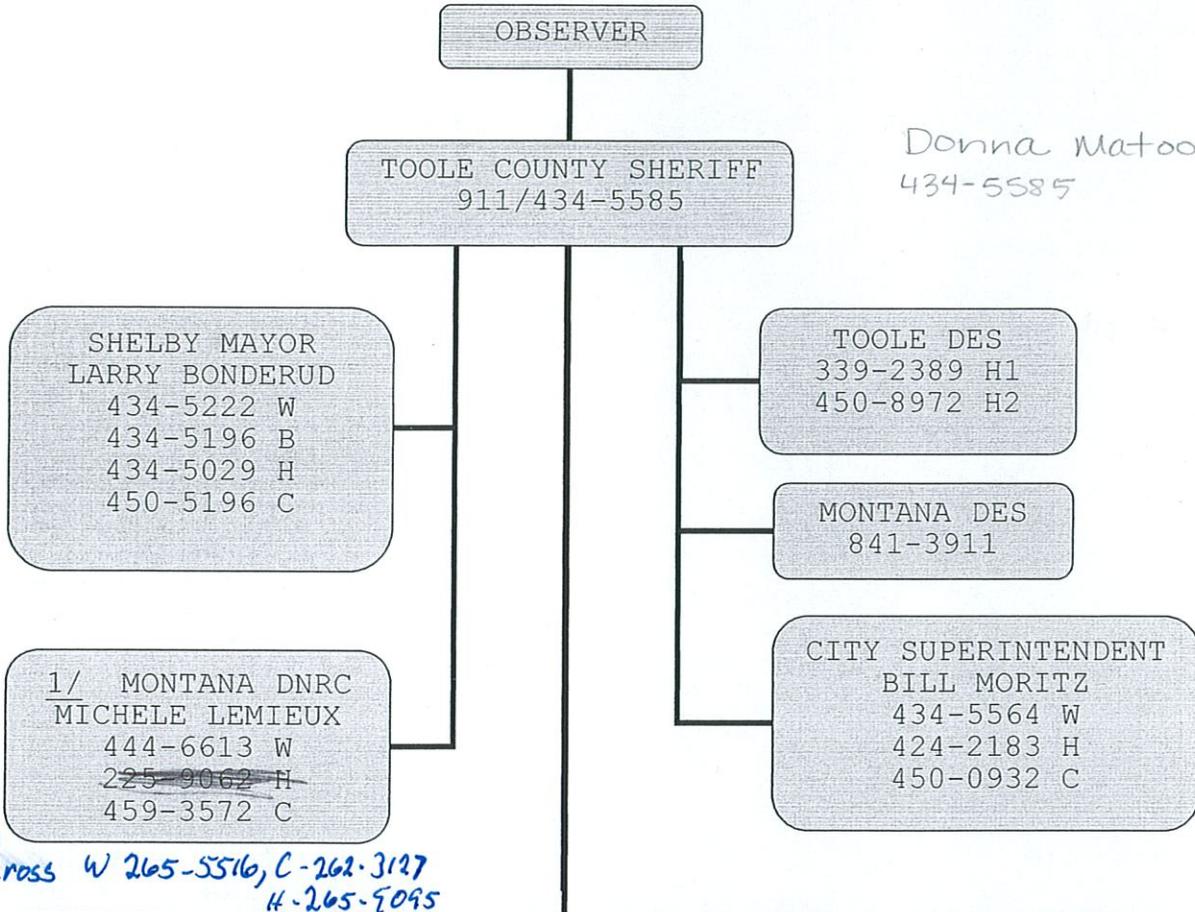
If these means fail, handle the immediate problems as well as you can, and periodically try to reestablish contact with the Sheriff's Office. The Toole County Sheriff's Department will issue warnings to the general public in accordance with the Toole County Emergency Operations Plan.

FIGURE 2-NOTIFICATION FLOWCHART

Figure 2

COWPATH/SULLIVAN DAMS
ACTUAL OR IMMINENT FAILURE
NOTIFICATION FLOWCHART

NEAREST PHONES TO THE DAM ARE:



EVACUUES: CALL THE FOLLOWING BEFORE ANY OTHER NOTIFICAITONS ARE MADE: KIM RUFF 434-2153, STAN RUSSELL 434-2156, BOB LONGCAKE 434-5043, WAYNE SCHWENKE 434-5870, OR JOHN ANDERSON 434-2089. THEN MAKE AGENCY NOTIFICATIONS. THEN MAKE ADDITIONAL NOTIFICATIONS (See Appendix C).

1/ If unable to reach Montana Department of Natural Resources in the event of an emergency, call Montana DES at 841-3911 and ask for the DES Duty Officer.

Potentially Hazardous Situation

A potentially hazardous situation is an event or condition not normally encountered in the routine operation of the dam and reservoir. Among the unusual occurrences that may affect the dam are embankment problems, failure of the spillways or outlet works, heavy precipitation or rapid spring snowmelt, landslides, earthquakes, erosion, theft, vandalism, acts of sabotage, and serious accidents. Potential problems, causes, consequences, and actions are presented in Appendix E. These occurrences may endanger the dam, the public, or the downstream valley and may necessitate a temporary or permanent revision of the dam's operating procedures. The City Superintendent or his designee will appropriately inspect and monitor conditions in response to unusual occurrences that may affect the dam's structures. Help in these situations can be obtained by notifying those people shown in Figure 3.

If the observed discovers an unusual condition of the dam embankment that could threaten the structure:

- a. Have a qualified engineer inspect the dam as soon as possible to determine whether emergency action is necessary
- b. Notify the Toole County Disaster and Emergency Services Coordinator of the potential problem.
- c. Contact Dam Safety Program of the Department of Natural Resources and Conservation.

When the City Superintendent calls either an engineer or the DNRC to report a problem, use the form in Appendix D to ensure you can provide sufficient information for the engineer to analyze the problems. In addition, prepare a sketch periodically if the problem develops further. The Manual for Operation and Maintenance of Dry Fork Dam includes further guidelines for courses of action to take to mitigate the effect of any problems. Continue to evaluate structure for failure and begin appropriate notifications if failure seems likely (see Figure 2).

Posting of the Notification Flowchart and Distribution of the Emergency Action Plan

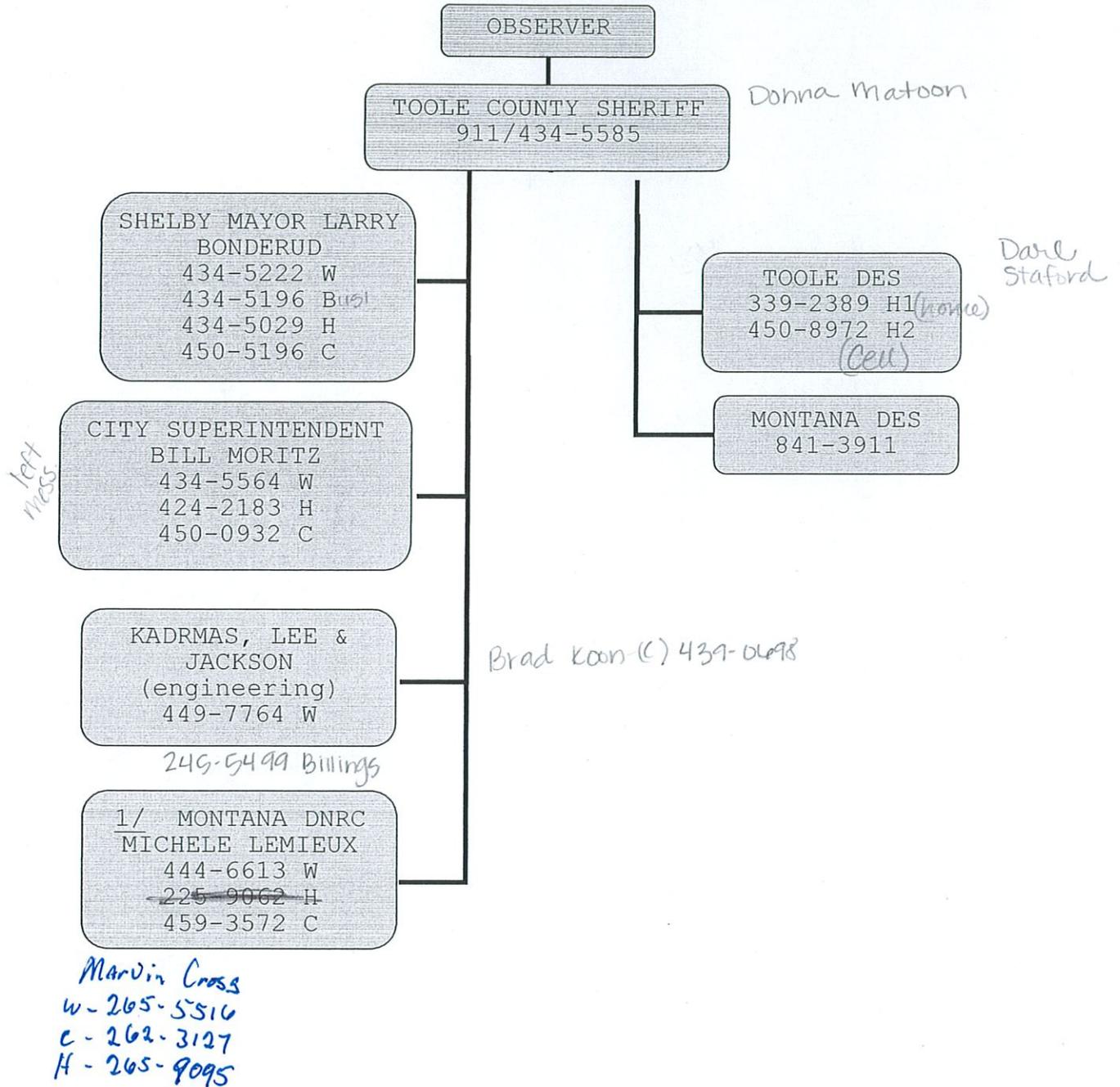
The Notification Flowchart is posted at the dam and a copy of the EAP is in the City Hall. The Toole County Sheriff's Office and the Toole County DES Coordinator also have copies of the plan.

FIGURE 3

COWPATH/SULLIVAN DAMS

POTENTIALLY HAZARDOUS SITUATION

NOTIFICATION FLOWCHART



1/ Principal notification is noted by solid lines. If the first individual in a sequence is not contacted, Toole County Sheriff's Department will provide notification to those following.

MITIGATION ACTION

Besides normal monitoring of the dam's condition the owner will provide continuous monitoring and inspection during and after extreme events such as storms and earthquakes. Information on the magnitude of an earthquake or storm can be obtained from the DNRC Dam Safety Program (444-9362). Actions are suggested to mitigate problems that may develop, but those actions should never be continued at the risk of injury or at the expense of lessening efforts related to evacuation.

POTENTIAL PROBLEMS AND IMMEDIATE RESPONSE ACTIONS

Potential problems, causes, consequences, and actions are presented in Appendix E.

EMERGENCY SUPPLIES AND RESOURCES

Soils suitable for emergency repairs are present in the original borrow areas used for construction of the facility. These areas are located at the west end of Sullivan Dam and on the southwest side of the connecting channel. Soils are also available at the City of Shelby landfill.

LOCAL CONTRACTORS

Shelby:	Toole County Road Department	434-2742
	Hiline Redi-Mix	434-5391
Conrad:	Sullivan Brothers Construction	278-7940
Cut Bank:	Alme Construction	873-4771
Sunburst:	Pro Automotive	937-7400

ENGINEERS

Kadrmass, Lee & Jackson, Helena, Montana	449-7764
--	----------

APPENDIX A

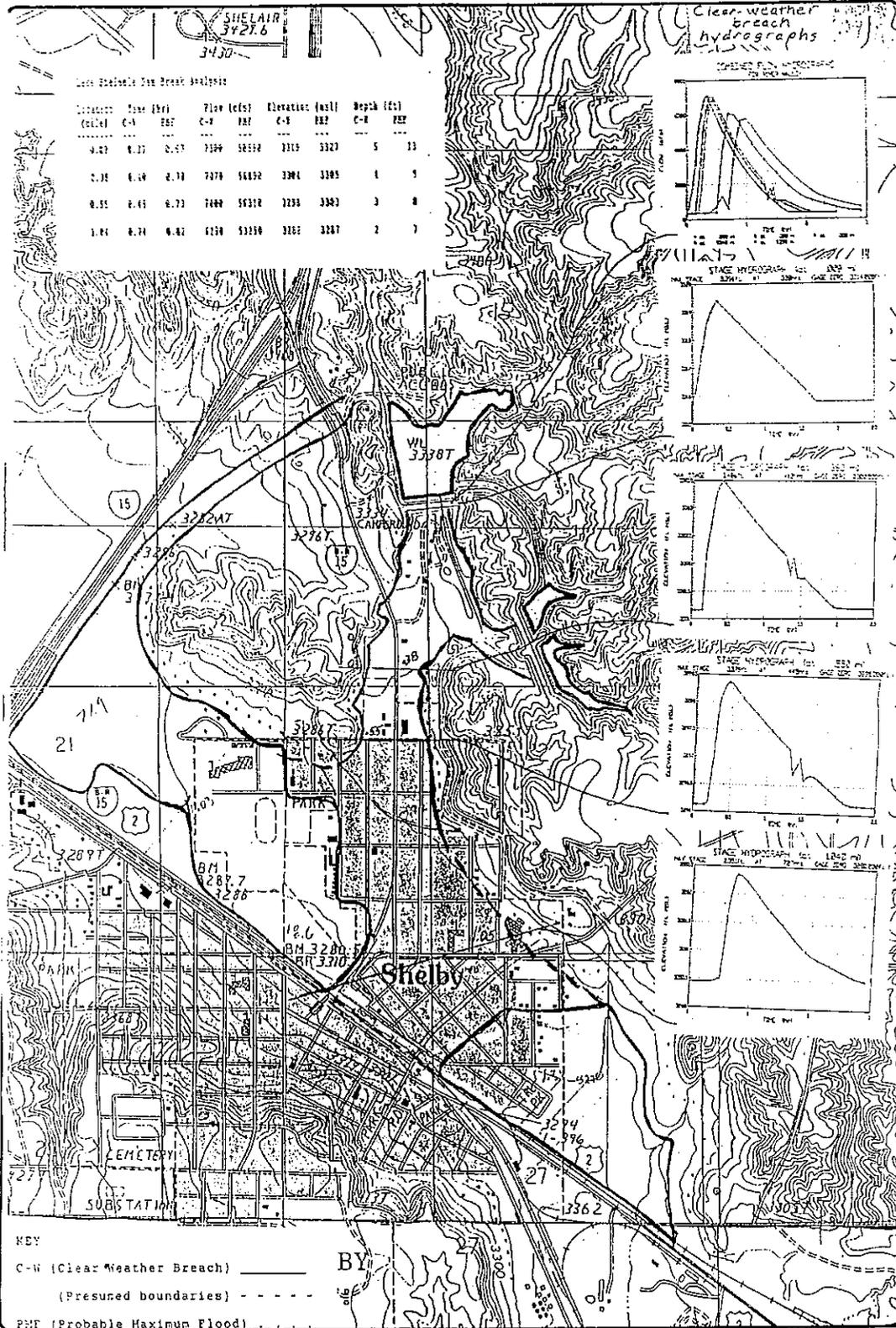
TECHNICAL DATA FOR COWPATH DAM AND SULLIVAN DAM 1/

Maximum Reservoir Capacity to the Crest of the Dam:	Cowpath: 940 acre feet Sullivan: 1,470 acre feet TOTAL (including connecting channel): 2,480 acre feet
Normal Reservoir Capacity Measured to the Principal Spillway Crest:	Cowpath: 190 acre feet Sullivan: 360 acre feet TOTAL (including connecting channel): 553 acre feet
Normal Water Depth Measured from the Streambed To the Crest of the Principal Spillway:	27 feet
Dam Height Measured from the Streambed to the Crest of the Dam:	49 feet
Dam Crest Width:	Cowpath: 18 feet Sullivan: 18 feet
Dam Width at Base:	Cowpath: 283 feet Sullivan: 283 feet
Length of Dam Crest:	Cowpath: 1,425 feet Sullivan: 750 feet
Outlet Capacity at Maximum Surcharge:	20 cubic feet per second
Principal Spillway Capacity at Maximum Surcharge:	35 cubic feet per second
Emergency Spillway Capacity at Maximum Surcharge:	3150 cubic feet per second
Date Constructed:	1967
Slope of Upstream Face of Dam:	Cowpath: 3H:1V with a 10 feet wide berm at elev. 3341.0 feet MSL Sullivan: 3H:1V with a 10 feet wide berm at elev. 3341.0 feet MSL
Slope of Downstream Face of Dam:	Cowpath: 2H:1V with a 10 feet wide berm at elev. 3341.0 feet MSL Sullivan: 2H:1V with a 10 feet wide berm at elev. 3341.0 feet MSL

1/ CSSA. January 1980. Phase 1 Inspection Report, City of
Shelby Watershed Dam

APPENDIX B

APPENDIX B



COW PATH AND SULLIVAN DAMS
 INUNDATION AND EVACUATION MAP

APPENDIX B
HKA ASSOCIATES
 ENGINEERS • PLANNERS
 8M334.101 | NOV 91

APPENDIX C

DAM INCIDENT REPORT FORM

DATE _____ TIME _____ A.M. / P.M.

NAME OF DAM _____

STREAM NAME _____

LOCATION _____

COUNTY _____

OBSERVER _____

OBSERVER TELEPHONE _____

NATURE OF PROBLEM _____

LOCATION OF PROBLEM AREA _____
(looking downstream)

EXTENT OF PROBLEM AREA _____

FLOW QUANTITY AND COLOR _____

WATER LEVEL IN RESERVOIR _____

IS SITUATION WORSENING? _____

EMERGENCY STATUS _____

CURRENT WEATHER CONDITIONS _____

ADDITIONAL COMMENTS _____

EMERGENCY ACTION PLAN

Names and Mailing Addresses

Larry J. Bonderud, Mayor
City of Shelby
112 1st St S
Shelby, MT 59474

Kadrmass, Lee & Jackson
1075 N Rodney, Suite 101
Helena, MT 59625-1567

Montana Disaster and Emergency
Services
PO Box 4789
Helena, MT 59604-4789

Michele Lemieux
Dam Safety Program
Montana DNRC
PO Box 201601
Helena, MT 59620-1601

Toole County Sheriff
PO Box 550
Shelby, MT 59474

Darrell Stafford
Toole County DES Coordinator
303 E Choteau
Shelby, MT 59474

Diane Grimm
TC DES Deputy Coordinator
422 Park Dr
Shelby, MT 59474

Bill Moritz
City Superintendent
City of Shelby
112 1st St S
Shelby, MT 59474

Montana Dam Safety Program
PO Box 202301
Helena, MT 59620-2301

Marvin Cross
Havre DNRC
PO Box 1828
Havre, MT 59501

APPENDIX E

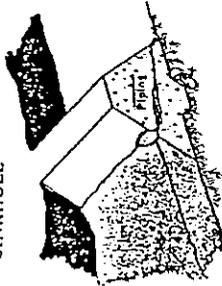
APPENDIX E

Potential Problems, Causes, Consequences and Action

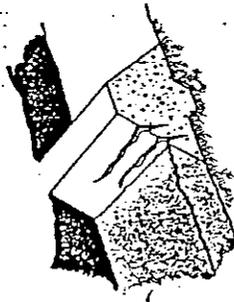
31 **FIGURES 5.3.4
INSPECTION GUIDEINES -
EMBANKMENT UPSTREAM SLOPE**

PROBLEM

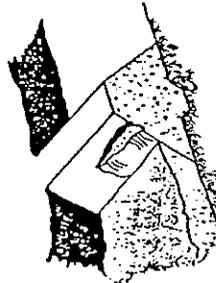
SINKHOLE



LARGE CRACKS



SLIDE, SLUMP OR SLIP



**SCARPS, BENCHES,
OVERSTEEP AREAS**

PROBABLE CAUSE

Piping or internal erosion of embankment materials or foundation causes a sinkhole. The caving in of an eroded cavern can result in a sink hole. A small hole in the wall of an outlet pipe can develop a sink hole. Dirty water at the exit indicates erosion of the dam.

A portion of the embankment has moved because of loss of strength, or the foundation may have moved, causing embankment movement.

Earth or rocks move down the slope along a slippery surface because of too steep a slope, or the foundation moves. Also, look for slides movement in reservoir basin.

Wave action, local settlement, or ice action cause soil and rock to erode and slide to the lower part of the slope forming a bench.

POSSIBLE CONSEQUENCES

HAZARDOUS

Piping can empty a reservoir through a small hole in the wall or can lead to failure of a dam as soil pipes erode through the foundation or a pervious part of the dam.

HAZARDOUS

Indicates onset of massive slide or settlement caused by foundation failure.

HAZARDOUS

A series of slides can lead to obstruction of the outlet or failure of the dam.

Erosion lessens the width and possible height of the embankment and could lead to increased seepage or overtopping of the dam.

RECOMMENDED ACTIONS

Inspect other parts of the dam for seepage or more sink holes. Identify exact cause of sink hole. Check seepage and leakage outflows for dirty water. A qualified engineer should inspect the conditions and recommend further actions to be taken.
ENGINEER REQUIRED

Depending on embankment involved, draw reservoir level down. A qualified engineer should inspect the conditions and recommend further actions to be taken.
ENGINEER REQUIRED

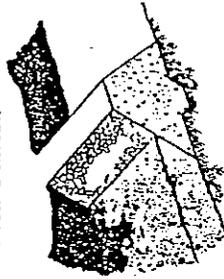
Evaluate extent of the slide. Monitor slide. (See Chapter 6.) Draw the reservoir level down if safety of dam is threatened. A qualified engineer should inspect the conditions and recommend further actions to be taken.
ENGINEER REQUIRED

Determine exact cause of scarp. Do necessary earthwork, restore embankment to original slope and provide adequate protection (bedding and riprap). See Chapter 7.

11 PROBLEM

BROKEN DOWN MISSING RIPRAP

Poor quality riprap has deteriorated. Wave action or ice action has displaced riprap. Round and angular riprap have rolled downhill.



POSSIBLE CONSEQUENCES

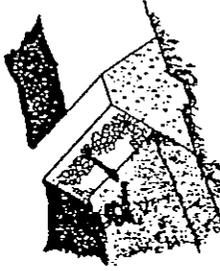
Wave action against these unprotected areas decreases embankment width.

RECOMMEND ACTIONS

Re-establish normal slope. Place bedding and competent riprap. (See Chapter 7.)

EROSION BEHIND POORLY GRADED RIPRAP

Similar-sized rocks allow waves to pass between them and erode small gravel particles and soil.



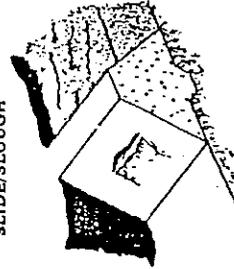
Soil is eroded away from behind the riprap. This allows riprap to settle, providing less protection and decreased embankment width.

Re-establish effective slope protection. Place bedding material. **ENGINEER REQUIRED** for design for gradation and size for rock for bedding and riprap. A qualified engineer should inspect the conditions and recommend further actions to be taken.

Figures 5.2.2 Inspection Guidelines - Downstream Slope

SLIDE/SLOUGH

1. Lack of or loss of strength of embankment material.
2. Loss of strength can be attributed to infiltration of water into the embankment or loss of support by the foundation.

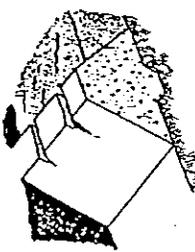


HAZARDOUS
Massive slide cuts through crest of upstream slope reducing fireboard and cross section. Subsequent collapse of overtopping can result.

1. Measure extent and displacement of slide.
2. If continued movement is seen, begin lowering water level until movement stops.
3. Have a qualified engineer inspect the condition and recommend further action.
ENGINEER REQUIRED

33 PROBLEM

TRANSVERSE CRACKING



PROBABLE CAUSE

Differential settlement of the embankment also leads to transverse cracking (e.g., center settles more than abutments).

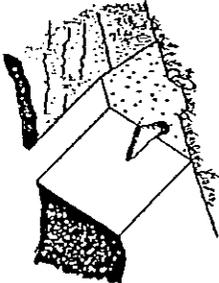
POSSIBLE CONSEQUENCES

HAZARDOUS
Settlement or shrinkage cracks can lead to seepage of reservoir water through the dam. Shrinkage cracks allow water to enter the embankment. This promotes saturation and increases freeze-thaw action.

RECOMMENDED ACTIONS

1. If necessary, plug upstream end of crack to prevent flows from the reservoir.
 2. A qualified engineer should inspect the conditions and recommend further actions to be taken.
- ENGINEER REQUIRED**

CAVE IN/COLLAPSE



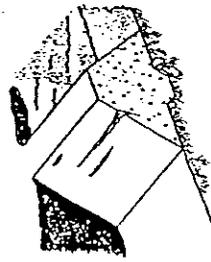
1. Lack of adequate compaction.
2. Rodent hole below.
3. Piping through embankment or foundation.

HAZARDOUS

Indicates possible wash out of embankment.

1. Inspect for and immediately repair rodent holes. Control rodents to prevent future damage.
 2. Have a qualified engineer inspect the condition and recommend further action.
- ENGINEER REQUIRED**

LONGITUDINAL CRACKING



1. Drying and shrinkage of surface material.
2. Downstream movement of settlement of embankment.

1. Can be an early warning of a potential slide.
2. Shrinkage cracks allow water to enter the embankment and freezing will further crack the embankment.
3. Settlement or slide showing loss of strength in embankment can lead to failure.

1. If cracks are from drying, dress area with well-compacted material to keep surface from drying out and natural moisture in.
 2. If cracks are extensive, a qualified engineer should inspect the condition and recommend further actions to be taken.
- ENGINEER REQUIRED**

SLUMP (LOCALIZED CONDITION)



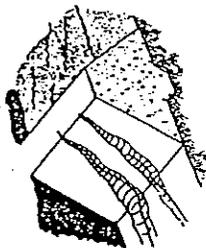
Preceded by erosion undercutting a portion of the slope. Can also be found on steep slopes.

Can expose impervious zone to erosion and lead to further slumps.

1. Inspect area for seepage.
 2. Monitor for progressive failure.
 3. Have a qualified engineer inspect the condition and recommend further action.
- ENGINEER REQUIRED**

34 PROBLEM

EROSION



PROBABLE CAUSE

Water from intense rainstorms or snow-melt carries surface material down the slope, resulting in continuous rought.

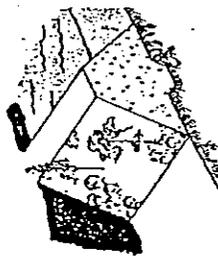
POSSIBLE CONSEQUENCES

Can be hazardous if allowed to continue. Erosion can lead to eventual deterioration of the downstream slope and failure of the structure.

RECOMMENDED ACTIONS

1. The preferred method to protect eroded areas is rock or riprap.
2. Re-establishing protective grasses can be adequate if the problem is detected early.

TREES/OBSCURING BRUSH

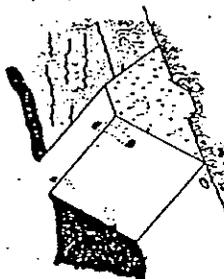


Natural vegetation in area.

Large tree roots can create seepage paths. Brush can obscure visual inspection and harbor rodents.

1. Remove all large, deep-rooted trees and shrubs on or near the embankment. Properly backfill void. (See Chapter 7.)
2. Control vegetation on the embankment that obscures visual inspection. (See Chapter 7.)

RODENT ACTIVITY

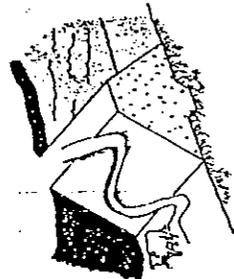


Over-abundance of rodents. Holes, tunnels and caverns are caused by animal burrowing. Certain habitats like cattail type plants and trees close to the reservoir encourage these animals.

Can reduce length of seepage path, and lead to piping failure. If tunnel exists through most of the dam, it can lead to failure of the dam.

1. Control rodents to prevent more damage.
2. Backfill existing rodent holes.
3. Remove rodents. Determine exact location of digging and extent of tunnelling. Remove habitat and repair damages. (See Chapter 7.)

LIVESTOCK/CATTLE TRAFFIC



Excessive travel by livestock especially harmful to slope when wet.

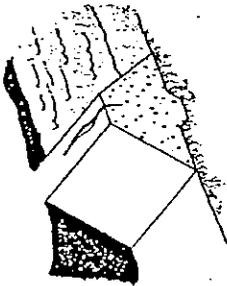
Creates areas bare of erosion protection and causes erosion channels. Allows water to stand. Area susceptible to drying cracks.

1. Fence livestock outside embankment area.
2. Repair erosion protection, i.e., riprap, grass.

35 Figures 5.3.3
Inspection Guidelines -
Embankment Crest

PROBLEM

LONGITUDINAL CRACK



PROBABLE CAUSE

1. Uneven settlement between adjacent sections or zones within the embankment.
2. Foundation failure causing loss of support to embankment.
3. Initial stages of embankment slide.

POSSIBLE CONSEQUENCES

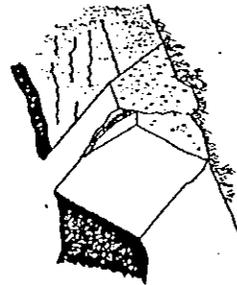
HAZARDOUS

1. Creates local areas of low strength within embankment. Could be the point of initiation of future structural movement, deformation, or failure.
2. Provides entrance point for surface run-off into embankment, allowing saturation of adjacent embankment area, and possible lubrication which could lead to localized failure.

RECOMMENDED ACTIONS

1. Inspect crack and carefully record location, length, depth, width, alignment, and other pertinent physical features. Immediately state out limits of cracking. Monitor frequently.
2. Engineer should determine cause of cracking and supervise steps necessary to reduce danger to dam and correct condition.
3. Effectively seal the cracks at the crest's surface to prevent infiltration by surface water.
4. Continue to routinely monitor crest for evidence of further cracking.
ENGINEER REQUIRED

VERTICAL DISPLACEMENT



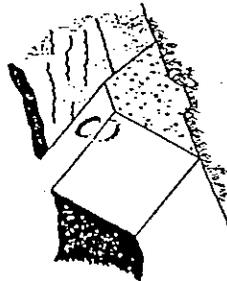
HAZARDOUS

1. Provides local areas of low strength within embankment which could cause future movement.
2. Leads to structural instability or failure.
3. Provides entrance point for surface water that could further lubricate failure plane.
4. Reduces available embankment cross section.

1. Vertical movement between adjacent sections of the embankment.
2. Structural deformation or failure caused by structural stress or instability, or by failure of the foundation.

1. Carefully inspect displacement and record its location, vertical and horizontal displacement, length, and other physical features. Immediately state out limits of cracking.
2. Engineer should determine cause of displacement and supervise all steps necessary to reduce danger to dam and correct condition.
3. Excavate area to the bottom of the displacement. Backfill excavation using competent material and correct construction techniques, and under supervision of engineer.
4. Continue to monitor area routinely for evidence of future cracking or movement.
ENGINEER REQUIRED

CAVE-IN ON CREST



1. Rodent activity.
2. Hole in outlet conduit is causing erosion of embankment material.
3. Internal erosion or piping of embankment material by seepage.
4. Breakdown of dispersive clays within embankment by seepage water.

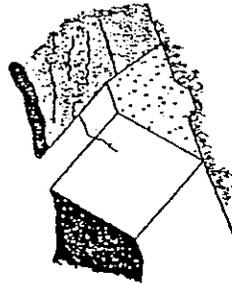
1. Void within dam could cause localized caving, sloughing, instability, or reduced embankment cross section.
2. Entrance point for surface water.

HAZARDOUS

1. Carefully inspect and record location and physical characteristics (depth, width, length) of cave in.
2. Engineer should determine cause of cave in and supervise all steps necessary to reduce threat to dam and correct condition.
3. Excavate cave in slope sides of excavation, and backfill hole with competent material using proper construction techniques. (See Chapter 1.) This should be supervised by engineer.
ENGINEER REQUIRED

34 PROBLEM

TRANSVERSE CRACKING



POSSIBLE CONSEQUENCES

HAZARDOUS

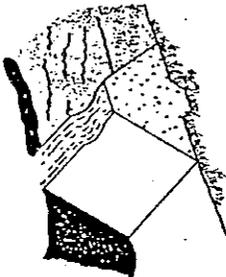
1. Can provide a path for seepage through the embankment cross section.
2. Provides local area of low strength within embankment. Future structural movement, deformation or failure could begin.
3. Provides entrance point for surface runoff to enter embankment.

RECOMMENDED ACTIONS

1. Inspect crack and carefully record crack location, length, depth, width, and other pertinent physical features. Stake out limits of cracking.
2. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and crest condition.
3. Excavate crack along crest to a point below the bottom of the crack. Then backfilling excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface runoff. (See Chapter 7.) This should be supervised by engineer.
4. Continue to monitor crest routinely for evidence of future cracking. (See Chapter 6.)

ENGINEER REQUIRED

CREST MISALIGNMENT



1. Area of misalignment is usually accompanied by low area in crest which reduces freeboard.
2. Can produce local areas of low embankment strength which may lead to failure.

1. Movement between adjacent parts of the structure.
2. Uneven deflection of dam under loading by reservoir.
3. Structural deformation or failure near area of misalignment.

LOW AREA IN CREST OF DAM



Reduces freeboard available to pass flood flows safely through spillway.

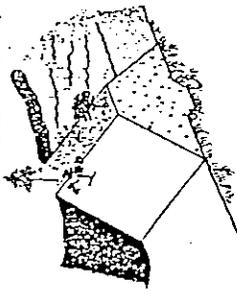
1. Excessive settlement in the embankment or foundation directly beneath the low area in the crest.
2. Internal erosion of embankment material.
3. Foundation spreading to upstream and/or downstream direction.
4. Prolonged wind erosion of crest area.
5. Improper final grading following construction.

1. Establish monuments along length of crest to determine exact amount, location, and extent of settlement in crest.
2. Engineer should determine cause of low area and supervise all steps necessary to reduce possible threat of the dam and correct condition.
3. Re-establish uniform crest elevation over crest length by placing fill in low area using proper construction techniques. This should be supervised by engineer.
4. Re-establish monuments across crest of dam and monitor monuments on a routine basis to detect possible future settlement.

ENGINEER REQUIRED

OBSCURING VEGETATION

Neglect of dam and lack of proper maintenance procedures.



POSSIBLE CONSEQUENCES

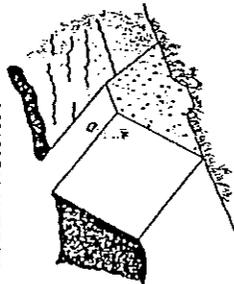
1. Obscures large parts of the dam, preventing adequate, accurate visual inspection of all parts of the dam. Problems which threaten the integrity of the dam can develop and remain undetected until they progress to a point that threatens the dam's safety.
2. Associated root systems develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root systems can provide paths for seepage. This reduces the effective seepage path through the embankment and could lead to possible piping situations.
3. Prevents easy access to all parts of the dam for operation, maintenance, and inspection.
4. Provides habitat for rodents.

RECOMMENDED ACTIONS

1. Remove all damaging growth from the dam. This would include removal of trees, bushes, brush, conifers, and growth other than grass. Grass should be encouraged on all segments of the dam to prevent erosion by surface runoff. Root systems should also be removed to the maximum practical extent. The void which results from removing the root system should be backfilled with well-compacted, well-compacted material.
2. Future undesirable growth should be removed by cutting or spraying, as part of an annual maintenance program. (See Chapter 7.)
3. All cutting or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside the reservoir basin.

RODENT ACTIVITY

Burrowing animals.

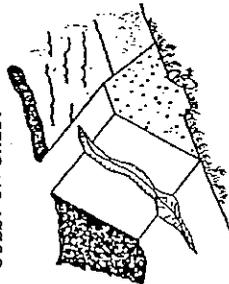


1. Entrance point for surface runoff to enter the dam. Could saturate adjacent portions of the dam.
2. Especially dangerous if hole penetrates dam below phreatic line. During periods of high storage, seepage path through the dam would be greatly reduced and a piping situation could develop.

1. Completely backfill the hole with competent, well-compacted material.
2. Initiate a rodent control program to reduce the burrowing animal population and to prevent future damage to the dam. (See Chapter 7.)

GULLY ON CREST

1. Poor grading and improper drainage of crest. Improper drainage causes surface runoff to collect and drain off crest at low point in upstream or downstream shoulder.
2. Inadequate spillway capacity which has caused dam to overtop.

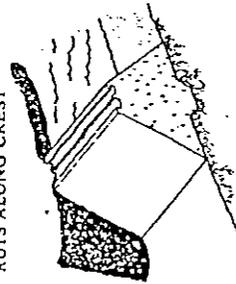


1. Can reduce available freeboard.
2. Reduces cross-sectional area of dam.
3. Inhibits access to all parts of the crest and dam.
4. Can result in a hazardous condition if due to overtopping.

1. Restore freeboard to dam by adding fill material in low area, using proper construction techniques. (See Chapter 7.)
2. Regrade crest to provide proper drainage of surface runoff.
3. If gully was caused by overtopping, provide adequate spillway which meets current design standards. This should be done by engineer.
4. Re-establish protective cover.

RUTS ALONG CREST

Heavy vehicle traffic without adequate or proper maintenance or proper crest surfacing.

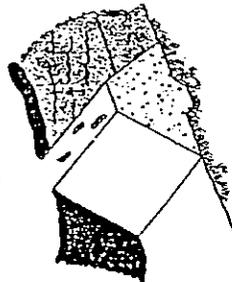


1. Inhibits easy access to all parts of crest.
2. Allows continued development of rutting.
3. Allows standing water to collect and saturate crest of dam.
4. Operating and maintenance vehicles can get stuck.

1. Drain standing water from ruts.
2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope. (See Chapter 7.)
3. Provide gravel or roadbase material to accommodate traffic.
4. Do periodic maintenance and regrading to prevent reformation of ruts.

34 PROBLEM

**PUDDLING ON CREST-
POOR DRAINAGE**



PROBABLE CAUSE

1. Poor grading and improper drainage of crest.
2. Localized consolidation or settlement on crest allows puddles to develop.

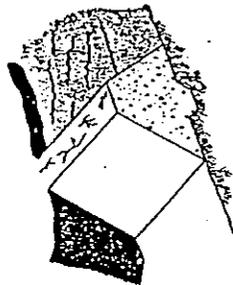
POSSIBLE CONSEQUENCES

1. Cause localized saturation of the crest.
2. Inhibits access to all parts of the dam and crest.
3. Becomes progressively worse if not corrected.

RECOMMENDED ACTIONS

1. Drain standing water from puddles.
2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope. (See Chapter 7.)
3. Provide gravel or roadbase material to accommodate traffic.
4. Do periodic maintenance and regrading to prevent reformation of low areas.

DRYING CRACKS



Material on the crest of dam expands and contracts with alternate wetting and drying of weather cycles. Drying cracks are usually short, shallow, narrow, and many.

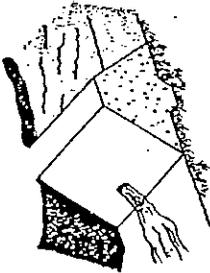
Provides point of entrance for surface runoff and surface moisture, causing saturation of adjacent embankment areas. This saturation, and later drying of the dam, could cause further cracking.

1. Seal surface of cracks with a light, impervious material. (See Chapter 7.)
2. Routinely grade crest to provide proper drainage and fill cracks. -OR-
3. Cover crest with non-plastic (not clay) material to prevent large moisture content variations.

39
Figures 5.3.4
Inspection Guidelines -
Embankment Seepage Areas

PROBLEM

EXCESSIVE QUANTITY
AND/OR MUDDY WATER
EXITING FROM A POINT



PROBABLE CAUSE

1. Water has created an open pathway, channel, or pipe through the dam. The water is eroding and carrying embankment material.
2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water.
3. Rodents, frost action or poor construction have allowed water to create an open pathway or pipe through the embankment.

POSSIBLE CONSEQUENCES

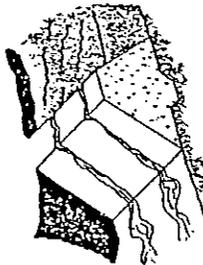
HAZARDOUS

1. Continued flows can saturate parts of the embankment and lead to slides in the area.
2. Continued flows can further erode embankment materials and lead to failure of the dam.

RECOMMENDED ACTIONS

1. Begin measuring outflow quantity and establishing whether water is settling, muddy, staying the same, or clearing up.
 2. If quantity of flow is increasing the water level in the reservoir should be lowered until the flow stabilizes or stops.
 3. Search for opening on upstream side and plug if possible.
 4. A qualified engineer should inspect the condition and recommend further actions to be taken.
- ENGINEER REQUIRED**

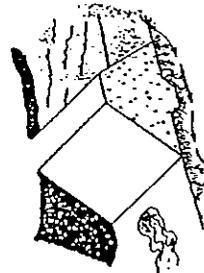
STREAM OF WATER
EXITING THROUGH CRACKS
NEAR THE CREST



HAZARDOUS
 Flow through the crack can cause failure of the dam.

1. Plug the upstream side of the crack to stop the flow.
2. The water level in the reservoir should be lowered until it is below the level of the cracks.
3. A qualified engineer should inspect the condition and recommend further action to be taken.

SEEPAGE WATER
EXITING AS A BOIL
IN THE FOUNDATION



Some part of the foundation material is supporting a flow path. This could be caused by a sand or gravel layer in the foundation.

HAZARDOUS
 Increased flows can lead to erosion of the foundation and failure of the dam.

1. Examine the soil for transportation of foundation materials.
 2. If soil particles are moving downstream, sandbags or earth should be used to create a dike around the boil. The pressures created by the water level within the dike may control flow velocities and temporarily prevent further erosion.
 3. If erosion is becoming greater, the reservoir level should be lowered.
 4. A qualified engineer should inspect the condition and recommend further actions to be taken.
- ENGINEER REQUIRED**

40 PROBLEM

SEEPAGE EXITING AT ABUTMENT CONTACT



PROBABLE CAUSE

- 1. Water flowing through pathways in the abutment.
- 2. Water flowing through the embankment.

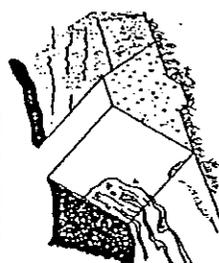
POSSIBLE CONSEQUENCES

HAZARDOUS
Can lead to erosion of embankment materials and failure of the dam.

RECOMMENDED ACTIONS

- 1. Study leakage area to determine quantity of flow and extent of saturation.
 - 2. Inspect daily for developing slides.
 - 3. Water level in reservoir may need to be lowered to assure the safety of the embankment.
 - 4. A qualified engineer should inspect the conditions and recommend further actions to be taken.
- ENGINEER REQUIRED**

LARGE AREA WET OR PRODUCING FLOW



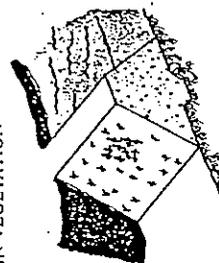
A seepage path has developed through the abutment or embankment materials and failure of the dam can occur.

HAZARDOUS

- 1. Increased flows could lead to erosion of embankment material and failure of the dam.
- 2. Saturation of the embankment can lead to local slides which could cause failure of the dam.

- 1. Stake out the saturated area and monitor for growth or shrinking.
 - 2. Measure any outflows as accurately as possible.
 - 3. Reservoir level may need to be lowered if saturated areas increase in size at a fixed storage level or if flow increases.
 - 4. A qualified engineer should inspect the condition and recommend further actions to be taken.
- ENGINEER REQUIRED**

MARKED CHANGE IN VEGETATION

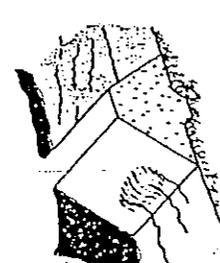


- 1. Embankment material are supplying flow paths.
- 2. Natural seeding by wind.
- 3. Change in seed type during early post construction seeding.

Can show a saturated area.

- 1. Use probe and shovel to establish if the materials in this area are better than surrounding areas.
 - 2. If test shows weakness, when surrounding areas do not, qualified engineer should inspect in condition and recommend further actions to be taken.
- ENGINEER REQUIRED**

BULGE IN LARGE WET AREA



Downstream embankment materials have begun to move.

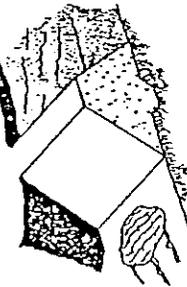
HAZARDOUS

Failure of the embankment result from massive sliding can follow these early movements.

- 1. Compare embankment cross section to the end of construction condition to see if observed condition may reflect end of construction.
 - 2. Stake out affected area and accurately measure outflow.
 - 3. A qualified engineer should inspect the condition and recommend further actions to be taken.
- ENGINEER REQUIRED**

4* PROBLEM

TRAMPOLINE EFFECT IN LARGE SOGGY AREA



PROBABLE CAUSE

1. Water moving rapidly through the embankment or foundation is being controlled or contained by a well-established turf root system.

POSSIBLE CONSEQUENCES

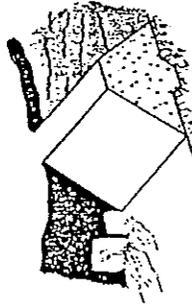
Condition shows excessive seepage in the area. If control layer of turf is destroyed, rapid erosion of foundation material could result. In failure of the dam.

RECOMMENDED ACTIONS

1. Carefully inspect the area for outflow quantity and any transported material.
2. A qualified engineer should inspect the condition and recommend further actions to be taken.

ENGINEER REQUIRED

LEAKAGE FROM ABUTMENTS BEYOND THE DAM

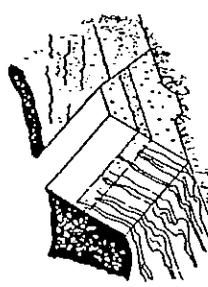


Water moving through crevices and fissures in the abutment materials.

Can lead to rapid erosion of abutment and evacuation of the reservoir. Can lead to massive slides near or downstream from the dam.

1. Carefully inspect the area to determine quantity of flow and amount of transported material.
2. A qualified engineer or geologist should inspect the condition and recommend further actions to be taken.

WET AREA IN HORIZONTAL BAND



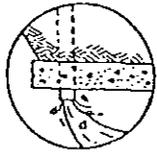
Frost layer or layer of sandy material in original construction.

HAZARDOUS
 1. Wetting of areas below the area of excessive seepage can lead to localized instability of the embankment, (SLIDES)
 2. Excessive flows can lead to accelerated erosion of embankment materials and failure of the dam.

1. Determine as closely as possible the flow being produced.
2. If flow increases, reservoir level should be reduced until flow stabilizes or stops.
3. Stake out the exact area involved.
4. Using hand tools, try to identify the material allowing the flow.
5. A qualified engineer should inspect the condition and recommend further actions to be taken.

ENGINEER REQUIRED

LARGE INCREASE IN FLOW OR SEDIMENT IN DRAIN-OUTFALL



A shortened seepage path or increased storage levels.

HAZARDOUS
 1. Higher velocity flows can cause erosion of drain then embankment materials.
 2. Can lead to piping failure.

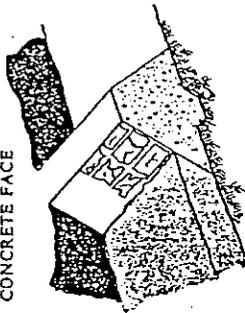
1. Accurately measure outflow quantity and determine amount of increase over previous flow.
2. Collect jar samples to compare turbidity.
3. If either quantity or turbidity has increased by 25%, a qualified engineer should evaluate the condition and recommend further actions.

ENGINEER REQUIRED

42 Figures 5.4
Inspection Guidelines -
Concrete Upstream Slope

PROBLEM

**CRACKED DETERIORATED
CONCRETE FACE**



PROBABLE CAUSE

Concrete deteriorated resulting from weathering. Joint filler deteriorated or displaced.

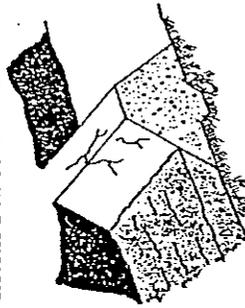
POSSIBLE CONSEQUENCES

Soil is eroded behind the face and cavities can be formed. Unsupported sections of concrete crack. Ice action may displace concrete.

RECOMMENDED ACTIONS

Determine cause. Either patch with grout or contact engineer for permanent repair method.
2. If damage is extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken.
ENGINEER REQUIRED

CRACKS DUE TO DRYING



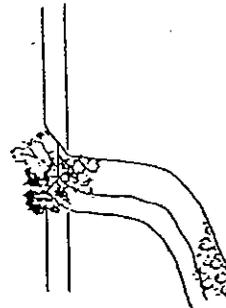
The soil loses its moisture and shrinks, causing cracks. NOTE: Usually seen on crest and downstream slope mostly.

Heavy rains can fill up cracks and cause small parts of embankment to move along internal slip surface.

1. Monitor cracks for increases in width, depth, or length.
2. A qualified engineer should inspect the condition and recommend further actions to be taken.
ENGINEER REQUIRED

Figures 5.5
Inspection Guidelines -
Spillways

**EXCESSIVE VEGETATION
OR DEBRIS IN CHANNEL**



Accumulation of slide materials, dead trees, excessive vegetative growth, etc., in spillway channel.

Reduced discharge capacity; overflow of spillway; overtopping of dam. Prolonged overtopping can cause failure of the dam.

Clean out debris periodically; control vegetation growth in spillway channel. Install log boom in front of spillway entrance to intercept debris.

43 PROBLEM

EROSION CHANNELS



PROBABLE CAUSE

Surface runoff from intense rainstorms or flow from spillway carries surface material down the slope, resulting in continuous troughs. Livestock traffic creates gullies where flow concentrates.

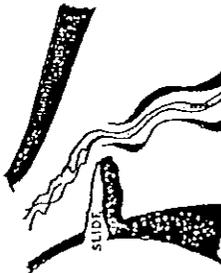
POSSIBLE CONSEQUENCES

Unabated erosion can lead to slides, slumps or slides which can result in reduced spillway capacity. Inadequate spillway capacity can lead to embankment overlapping and result in dam failure.

RECOMMENDED ACTIONS

Photograph condition. Repair damaged areas by replacing eroded material with compacted fill. Protect areas against future erosion by installing suitable rock riprap. Revegetate area if appropriate. Bring condition to the attention of the engineer during next inspection.

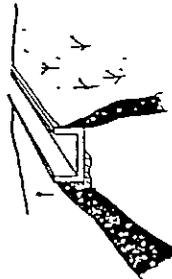
EXCESSIVE EROSION IN EARTH SLIDE CAUSES CONCENTRATED FLOWS



Disturbed flow pattern; loss of material, increased sediment load downstream; collapse of banks; failure of spillway; can lead to rapid evacuation of the reservoir through the severely eroded spillway.

Discharge velocity too high; bottom and slope material loose or deteriorated; channel and bank slopes too steep; bars and sill uncorrected; poor construction; protective surface failed.

END OF SPILLWAY CHUTE UNDERCUT

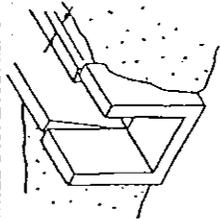


HAZARDOUS
Structural damage to spillway structure; collapse of slab and wall lead to costly repair.

Poor configuration of stilling basin area. Highly erodible materials. Absence of cutoff wall at end of chute.

Downstream area clean out eroded area and properly backfill. Improve stream channel below chute; provide properly sized riprap in stilling basin area. Install cutoff wall.

WALL DISPLACEMENT



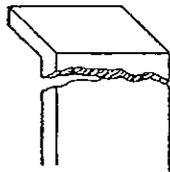
Poor workmanship; uneven settlement of foundation; excessive earth and water pressure; insufficient steel bar reinforcement of concrete.

Minor displacement will create eddies and turbulence in the flow, causing erosion of the soil behind the wall. Major displacement will cause severe cracks and eventual failure of the structure.

Reconstruction should be done according to sound engineering practices. Foundation should be carefully prepared. Adequate weep holes should be installed to relieve water pressure behind wall. Use enough reinforcement in the concrete. Anchor walls to prevent further displacement. Install sills between spillway walls if needed. Clean out and backflush drains to assure proper operation. Consult an engineer before action is taken.
ENGINEER REQUIRED

44 PROBLEM

LARGE CRACKS



PROBABLE CAUSE

Construction defect; local concentrated stress; local material deterioration; foundation failure, excessive backfill pressure.

POSSIBLE CONSEQUENCES

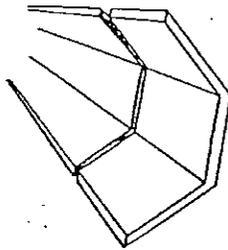
HAZARDOUS

Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure.

RECOMMENDED ACTIONS

Large cracks without large displacement should be repaired by patching. Surrounding areas should be cleaned or cut out before patching material is applied. (See Chapter 7.) Installation ofweep holes or other actions may be needed.

OPEN OR DISPLACED JOINTS



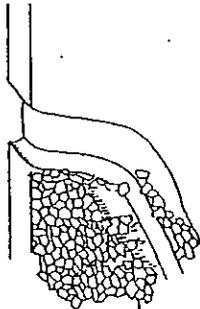
Excessive and uneven settlement of foundation; sliding of concrete slab; construction joint too wide and not controlled. Sealant deteriorated and washed away.

HAZARDOUS

Erosion of foundation material may weaken support and cause further cracks; pressure induced by water flowing over displaced joints may wash away wall or slab, or cause extensive undermining.

Construction joint should be no wider than 1/2 inch. All joints should be sealed with asphalt or other flexible materials. Water stops should be used where feasible. Clean the joint, replace eroded materials, and seal the joint. Foundations should be properly drained and prepared. Underdrains of chute slabs should have ribs of enough depth to prevent sliding. Avoid steep chute slopes. ENGINEER REQUIRED

BREAKDOWN AND LOSS OF RIPRAP



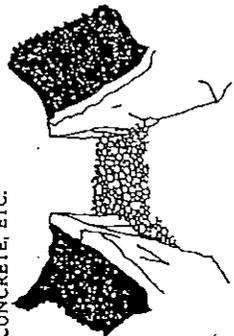
Slope too steep; material poorly graded; failure of subgrade; flow velocity too high; improper placement of material; bedding material of foundation washed away.

HAZARDOUS

Erosion of channel bottom and banks; failure of spillway.

Design a stable slope for channel bottom and banks. Riprap material should be well graded (the material should consist small, medium, and large particles). Sub-grade should be properly prepared before placement of riprap. Install filter fabric if necessary. Control flow velocity in the spillway by proper design. Riprap should be placed according to specification. Services of an engineer are recommended. ENGINEER REQUIRED

MATERIAL DETERIORATION, SPALLING AND DISINTEGRATION OF RIPRAP, CONCRETE, ETC.



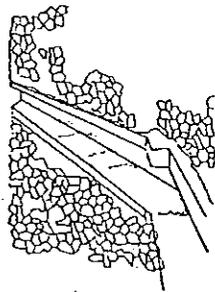
Use of unsound or defective materials; structures subject to freeze-thaw cycles; improper maintenance practices; harmful chemicals.

Structure life will be shortened; premature failure.

Avoid using shales or sandstone for riprap. Add alkalis to cement when mixing concrete. Use only clean, good quality aggregates in the concrete. Steel bars should have at least 1 inch of concrete cover. Concrete should be kept wet and protected from freezing during curing. Timber should be treated before using.

45 PROBLEM

POOR SURFACE DRAINAGE



PROBABLE CAUSE

No weep holes; no drainage facility; plugged drains.

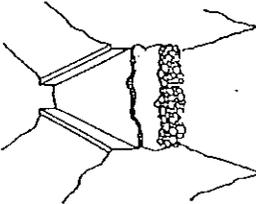
POSSIBLE CONSEQUENCES

Wet foundation has lower supporting capacity; uplift pressure resulting from seepage water may cause damage to spillway chute; accumulation of water may also increase total pressure on spillway walls and cause damage.

RECOMMENDED ACTIONS

Install weep holes on spillway walls. Inner end of holes should be surrounded and packed with graded filtering material. Install drain system under spillway near downstream end. Clean out existing weep holes. Back-flush and rehabilitate drain system under the supervision of an engineer.
ENGINEER REQUIRED

CONCRETE EROSION, ABRASION, AND FRACTURING

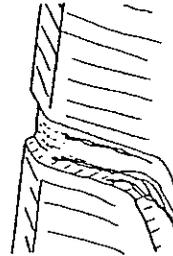


Flow velocity too high (usually occurs at lower end of chute in high dams); rolling of gravel and rocks down the chute; cavity behind or below concrete slab.

Pock marks and spalling of concrete surface may progressively become worse; small hole may cause undermining of foundation, leading to failure of structure.

Remove rocks and gravel from spillway chute before flood season. Raise water level in stilling basin. Use good quality concrete. Assure concrete surface is smooth.
ENGINEER REQUIRED

LEAKAGE IN OR AROUND SPILLWAY



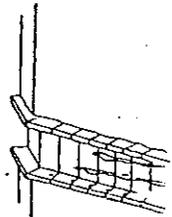
1. Cracks and joints in seepage formation at spillway are permitting seepage.
2. Gravel or sand layers at spillway are permitting seepage.

HAZARDOUS

1. Could lead to excessive loss of stored water.
2. Could lead to a progressive failure if velocities are high enough to cause erosion of natural materials.

1. Examine exit area to see if type of material can explain leakage.
2. Measure flow quantity and check for erosion of natural materials.
3. If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops.
4. A qualified engineer should inspect the condition and recommend further actions to be taken.
ENGINEER REQUIRED

TOO MUCH LEAKAGE FROM SPILLWAY UNDER DRAINS



Drain or cutoff may have failed.

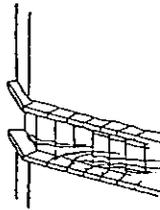
HAZARDOUS

1. Excessive flows under the spillway could lead to erosion of foundation material and collapse of parts of the spillway.
2. Uncontrolled flows could lead to loss of stored water.

Same as above.

44 PROBLEM

SEEPAGE FROM A CONSTRUCTION JOINT OR CRACK IN CONCRETE STRUCTURE



Figures 5.6 Inspection Guidelines - Inlets, Outlets and Drains OUTLET PIPE DAMAGE

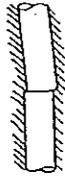
CRACK



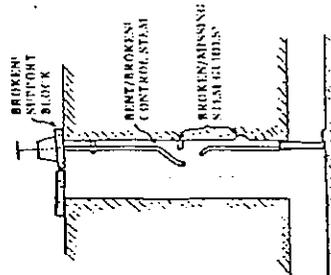
HOLE



JOINT OFFSET



CONTROL WORKS



PROBABLE CAUSE

Water is collecting behind structure because of insufficient drainage or blocked weep holes.

POSSIBLE CONSEQUENCES

1. Can cause walls to tip in and over. Flows through concrete can lead to rapid deterioration from weathering.
2. If the spillway is located within the embankment, rapid erosion can lead to failure of the dam.

RECOMMENDED ACTIONS

1. Check area behind wall for puddling of surface water.
2. Check and clean as needed, drain outfalls, lines, and weep holes.
3. If condition persists a qualified engineer should inspect the condition and recommend further actions to be taken.

Settlement impact.

Rust (steel pipe)
Erosion (concrete pipe)
Cavitation

Settlement or poor construction practices.

1. **BROKEN SUPPORT BLOCK**
Concrete deterioration. Excessive force exerted on control stem by trying to open gate when it was jammed.

2. **BENT/BROKEN CONTROL STEM**
Rust. Excess force used to open or close gate. Inadequate or broken stem guide.

3. **BROKEN/MISSING STEM GUIDES**
Rust. Inadequate lubrication. Excess force used to open or close gate when it was jammed.

Excessive seepage, possible internal erosion.

HAZARDOUS
Excessive seepage, possible internal erosion.

HAZARDOUS
Provides passageway for water to exit or enter pipe, resulting in erosion of internal materials of the dam.

Causes control support block to tilt control stem may bend. Control head work may settle. Gate may not open all the way. Support block may fall completely, leaving outlet inoperable.

HAZARDOUS
Outlet inoperable.

Loss of support for control stem. Stem may buckle and break under even normal use. (As in this example).

Check for evidence of water seepage entering or exiting pipe at crack/hole/etc.

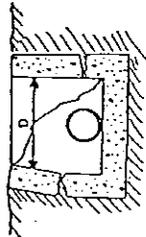
Tap pipe in vicinity of damaged area, listening for hollow sound which shows a void has formed along the outside of the conduit.

If a progressive failure is suspected, request engineering advice.

Any of these conditions can mean the control is either inoperable or at best partly operable. Use of the system should be minimized or discontinued. If the outlet system has a second control valve, consider using it to regulate releases until repairs can be made. Engineering help is recommended.

47 PROBLEM

FAILURE OF CONCRETE
OUTFALL STRUCTURE



PROBABLE CAUSE

Excessive side pressures on nonreinforced concrete structure. Poor concrete quality.

POSSIBLE CONSEQUENCES

HAZARDOUS
Loss of outfall structure exposes embankment to erosion by outlet release.

RECOMMENDED ACTIONS

1. Check for progressive failure by monitoring typical dimension, such as "D" shown in figure.
2. Repair by patching cracks and supplying drainage around concrete structure. Total replacement of outfall structure may be needed.

OUTLET RELEASES ERODING
TOE OF DAM



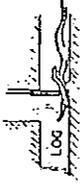
Outlet pipe too short. Lack of energy-dissipating pool or structure at downstream end of conduit.

HAZARDOUS
Erosion of toe oversteepens downstream slope, causing progressive sloughing.

1. Extend pipe beyond toe (use a pipe of same size and material, and form watertight connection to existing conduit).
2. Protect embankment with riprap over suitable bedding.

VALVE LEAKAGE

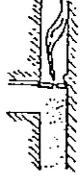
DEBRIS STUCK UNDER GATE



Trashrack missing or damaged.

Gate will not close. Gate or stem may be damaged in effort to close gate.

CRACKED GATE LEAF



Ice action, rust, affect vibration, or stress resulting from forcing gate closed when it is jammed.

Gate-leaf main fall completely, evacuating reservoir.

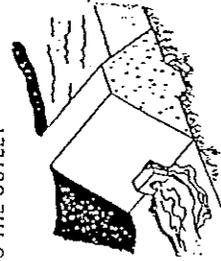
DAMAGE GATE SEAT
OR GUIDES



Rust, erosion, cavitation, vibration, or wear.

Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.

SEEPAGE WATER EXITING
FROM A POINT ADJACENT
TO THE OUTLET



1. A break in the outlet pipe.
2. A path for flow has developed along the outside of the outlet pipe.

HAZARDOUS

Continued flows can lead to rapid erosion of embankment materials and failure of the dam.

1. Thoroughly investigate the area by probing and/or shovelling to see if the cause can be determined.
 2. Determine if leakage water is carrying soil particles.
 3. Determine quantity of flow.
 4. If flow increases, or if carrying embankment materials, reservoir level should be lowered until leakage stops.
 5. A qualified engineer should inspect the condition and recommend further action to be taken.
- ENGINEER REQUIRED**

Minimize use of valve until guides/seats can be repaired. If cavitation is the cause, check to see if air vent pipe exists, and is unobstructed.

Use valve only in fully open or closed position. Minimize use of valve until leaf can be repair or replaced.

Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trashrack.